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G1A

(54) Infrared gas detector

(57) An infrared gas detector for methane uses a sensor head connected by optical fibres and measures transmission through the gas at a wavelength coinciding with an absorption line of the gas.

A reference is established by making a number of measurements outside the absorption band in an IR spectrum analyser and calculating a reference level in the center of the absorption band. The ratio between calculated reference value and measured value in the absorption band is a measure of the gas concentration in the sensor head.

The IR spectrum analyser is implemented by the aid of a pivotal optical interference filter, whose center wavelength will change with the angle of incidence of the incident collimated light beam. Thus, the filter is secured to a pivotal axis controlled by a servo motor or an optical scanner. The control signal is provided by a microcomputer.

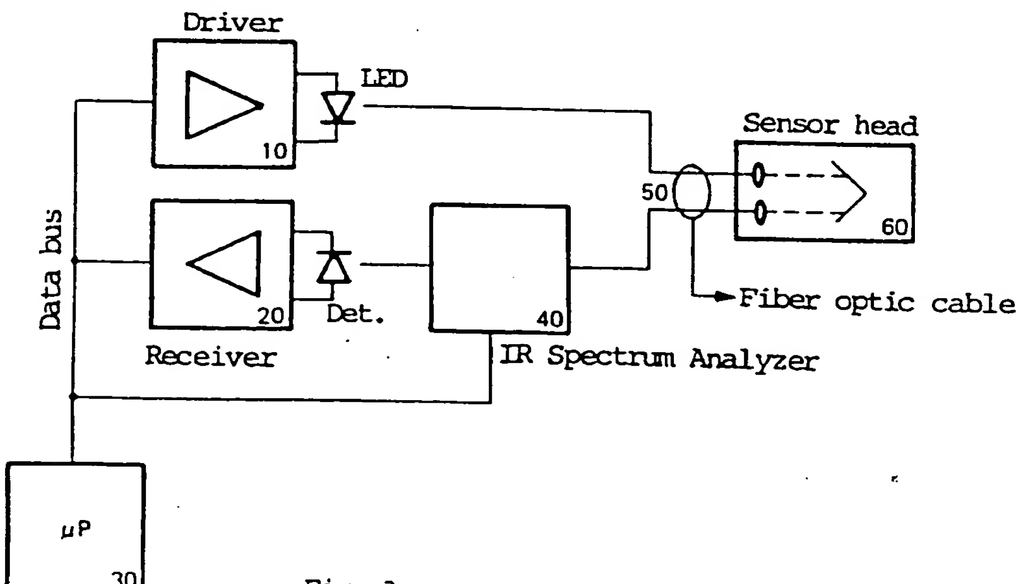

Fig. 3

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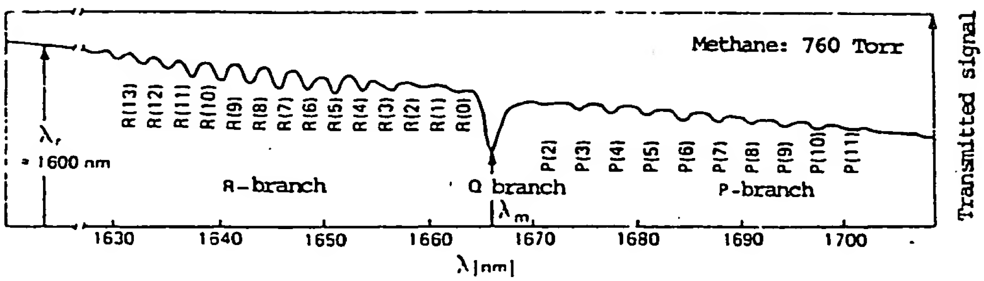

Fig. 1

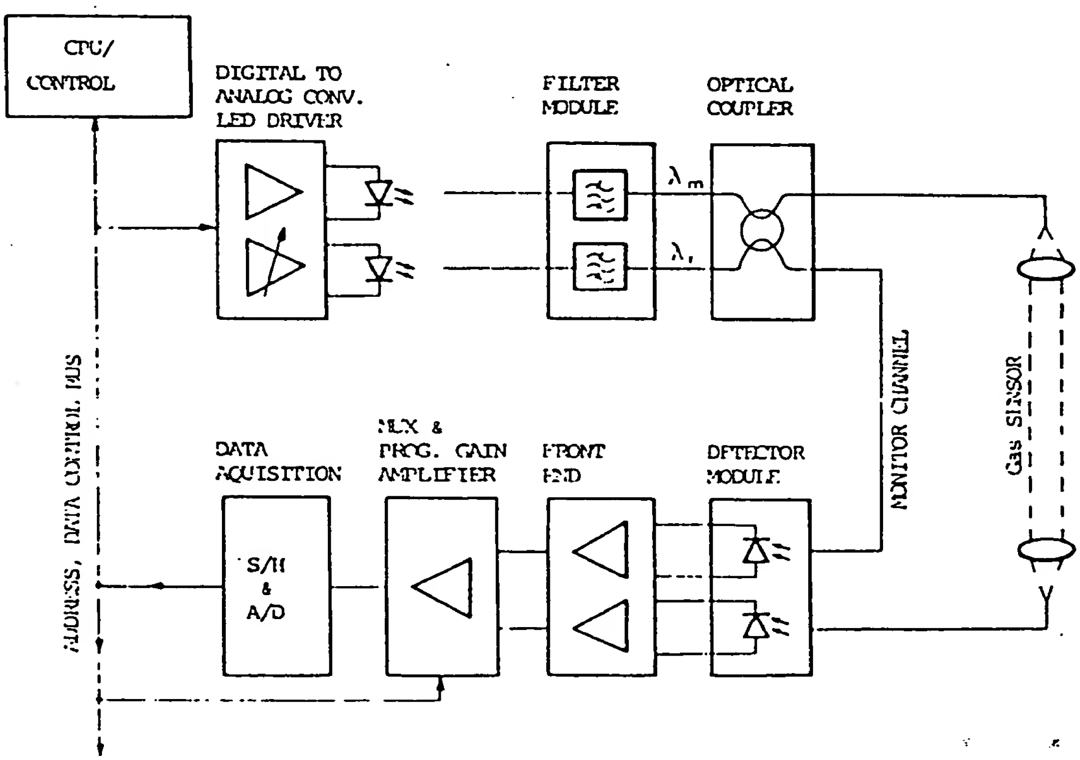

Fig. 2

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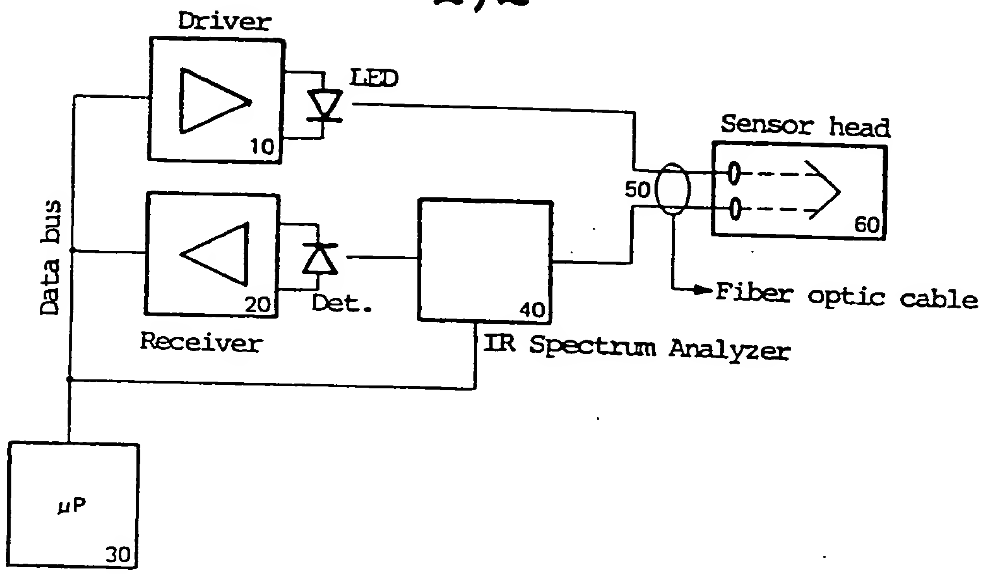

Fig. 3

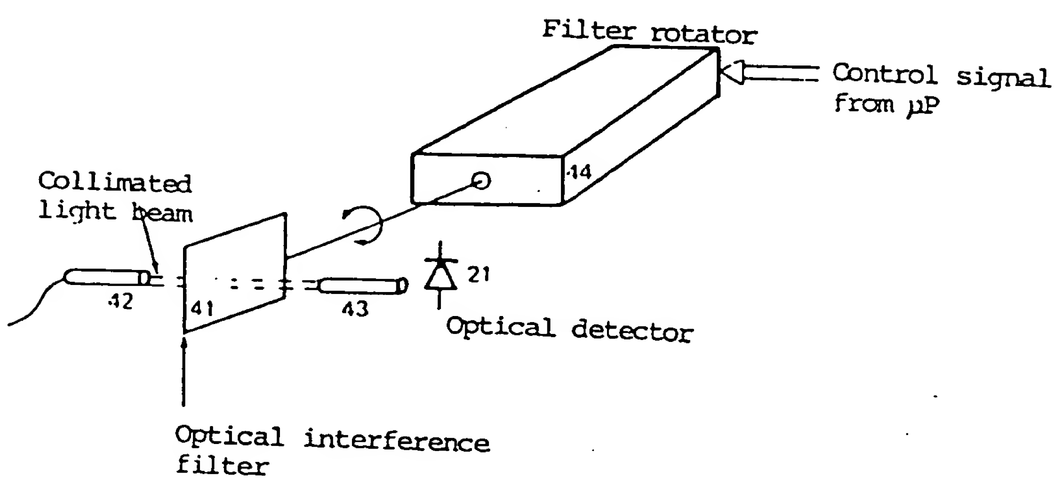

Fig. 4

SPECIFICATION

An infrared fiber-optic gas d tector

The invention relates to a fiber-optic measuring system for monitoring and measuring gases, based on infrared absorption spectroscopy. Measuring results in an optical signal that is spectrally analyzed in a special unit in the control module of the system. Said control module that is connected with the sensor per se by optical fibers may be positioned at great distance from the point of measuring the gas.

The invention is of special interest in connection with the detection of concentrations of e.g. methane gas entailing the danger of explosion. In this connection the fiber optic system has unique advantages as regards operation in environments where there is danger of explosion, e.g. environments found on offshore oil and gas producton plants.

Infrared absorption techniques for the detection of gases are well known. In recent years several approaches have, also, been disclosed involving optical fibers for transmission of the infrared light signals to and from the gas measuring cell. Thus, a completely passive and cold solution with a sensor loop completely safe per se is achieved. Reference is made to the following three publications disclosing the known technology:

1. B. Culshaw, "Optical fibre transducers", The Radio and Electronic Eng., Vol. 52, No. 6, June 1982, p. 283.
2. K. Chan et al., "An Optical-Fiber-Based Gas Sensor for Remote Absorption Measurement of Low-Level CH_4 Gas in the Near-Infrared Region", J. of Lightwave Techn., Vol. LT-2, No. 3, June 1984, p. 234.
3. A. Hordvik et al., "A Fiber Optic Gas Detection System", Proc. 9th ECOC, Geneva, 23–26 Oct. 1983, p. 317.

The basis of the present invention is a fiber optic methane detector on the basis of the principle disclosed in Item 3 above, and the realization of which is further described in reference 4): S. Stueflotten et al., "An infrared fibre optic gas detection system", Proc. 2nd OFS, Stuttgart, 5–7 Sept. 1984, p. 87. Reference is made to Fig. 2 for an illustration of the principle.

The basis of infrared detection of various gases is the measurement of an optical effect on a wave length coinciding with a line of absorption in the spectrum of the gas in question, e.g. methane. The transmission across the gas volume is according to Beer-Lambert's law, and the absorption on the chosen wave length will depend on the concentration, pressure and duration of absorption in the gas, as well as the relation between optic band width and the width of the absorption line.

In addition to gas absorption, other effects, as pollution, dimming and other mechanisms of loss, inter alia, in the fiber channel may further reduce the received power. In order to prevent said losses from resulting in false signals a differential absorption technique is used, light on one or several other reference wave lengths outside the line of absorption of the gas to be detected is transmitted simultaneously in the sensor loop. It is important that the mechanism of loss not due to gas absorption delivers identical contributions on the measuring and reference wavelength. An example of the positioning of the measuring (λ_m) and the reference wavelength (λ_r) is shown in Fig. 1, which also shows the $2\nu_3$-band in the methane spectrum.

Assuming that the emitted power is identical on both wavelengths and that the detector has the same responsivity to both wave lengths, the relation between detector signals will be an expression of the gas absorption. This is, however, a precondition being far from fulfilled. In a practical system both the emitted power on the two wavelengths and the detector responsivity will vary. An approach close at hand would, thus, be to monitor the emitted power on both wavelengths. A system which in principle attends to power monitoring and damping supervision in this manner is shown in Fig. 2.

Such a system in principle will be able to detect gas with great accuracy. However, in practice said system has some weak points, the most important being:

1. The relationship between the referance wave length and the measuring wave length will depend on the cable length. Consequently the system must be calibrated after installation.
2. Severe demands must be made on some of the components. This, above all, concerns the optical connector and the detectors. Regardning the connector it is important that the splitting ratio does not change due to aging, temperature, mechanical influences or the like. As regards the two detectors it is critical that the spectral responsivity changes equally as a function of temperature and time.
3. A different mode distribution in the transmission fiber and the sensor head may also be a problem. Due to this perturbations of fibers and contacts may cause a different damping on the two wavelengths. In the sensor head partial dimming of the light beam will have the same effect. Both changes will be detected as a change/drift of the gas concentra-

tion.

4. The structure comprises a comparatively large amount of components resulting in a comparatively expensive structure.

These weaknesses and disadvantages of the known system resulted in the fact that a new principle, disclosed in the following, was developed. With the present invention it is possible to implement an accurate and stable fiber optic gas detector having the advantages following from this in practice.

As shown in Fig. 1, the absorption spectrum of methane comprises several distinct lines within the transmission window of quartz fiber. The strongest absorption line is found on the Q branch of the spectrum at 1666 nm. A condition and a basic idea behind the new principle is that all parameters having spectral dependence very slowly in relation to the absorption lines of methane. For the Q-branch having a bandwidth at 50% of approximately 1.5nm, the requirements will be met satisfactorily for fiber damping variations, light source variations, and detector variations. Pollutions having a varying spectral absorption but lacking characteristical lines will also be included in the category of parameters. The same will also be valid as regards some interference effects having long periodicity in relation to the absorption band.

The principle is as follows: On the basis of a number of measurements on wavelengths outside the absorption line (e.g. the Q branch) the signal level in the center of the absorption line is calculated. Then the signal level is measured in that point. The ratio between the calculated value and the measured signal value is a measure of the absorption in the sensor head. The calculated value may e.g. be based on a Lagrange interpolation between measuring points. In practice it will be of interest to use 3–5 measuring points/wavelength channels. If the condition of slow spectral variations is fulfilled the ratio between measured and calculated value will solely be a function of the methane concentration other damping mechanism influencing the measured value and the calculated value equally. The system is indicated in a block diagram in Fig. 3.

Transmitter block (10) by the aid of a light emitting diode (LED) transmits light having wave lengths within the area where it is of interest to analyze the spectrum. The light is modulated by a quare signal controlled by microcomputer (30) or by a variable-frequency oscillator in the driver (10). The light is coupled into the fiber optic cable (50) extending to the sensor head (60). The receiver (20) detects light that has passed through the fiber optic sensor loop and the IR spectrum alalyser (40). Receiver (20) detects the light intensity synchronously with the modulating signal in transmitter (10). It is also synchronized with the adjustment of IR spectrum analyser.

It is a task of microcomputer (30) to calculate the reference value of the measuring wavelength on the basis of the light level on the single wavelengths to which the IR spectrum analyser (40) is adjusted sequentially. The gas concentration is calculated on the basis of this result. Block (30) will also generate synchronizing signals in the system, as well as provide communication with the surroundings. Calibration of the system is achieved by inserting a calibration cell having a known concentration of the gas in question into sensor head (60).

The realization of IR spectrum analyser (40) is a central feature of the present invention. It has a multi-channel function being sequencially adjustable to different wavelengths. Said analyser comprises a rotating, narrow band optical interference filter. The control signal to rotary mechanism (44) arrives from microcomputer (30). Microcomputer (30), thus, always knows what wavelength is transmitted.

The center wavelength of narrow band dielectric intereference filters among others is determined by the angle of incidence of the incident collimated light beam. The light beam is collimated by a Selfoc-lens (42) connected to the introduced fiber. A corresponding lens (43) is utilized for focusing the transmitted light onto the photo detector (21).

The following theoretical relation is valid between transmitted wavelength λ and angular momentum ϕ:

$$\lambda = \lambda_o\sqrt{1 - \frac{1}{n^2}\sin^2\phi}$$

Here λ_o is the center wave to filter on right-angled incidence, n is the effective refractive index in the filter. The center wavelength may now be reduced by turning the filter away from the normal incidence, i.e. by inclinding the filter in the beam. In a practical case the filter may be turned within 30° and, thus, the spectrum may be analysed on wavelengths within a band of approximately 60 nm around 1650 nm.

The block diagram of Fig. 4 in principle shows th realization of such a IR spectrum analyser based on turning an optical interference filter (41). The optical filter is secured to a pivotal axis moved by a rotary means (44). This may be a servo or an optical scanner. It is possible to control it to various rotational angles, e.g. 3–5, by control signals from a microcomputer (30).

CLAIMS

1. A process in gas detection, wherein light is transmitted through th gas medium to be examined and is then spectrum analysed for absorption of a determined wavelength, the light to and from the measuring point is passed through optic fibers and that the absorption is determined on the basis of the ratio between a calculated signal level based on measurements outside said predetermined wavelength and the measures signal level of the wavelength.

2. A process in spectrum analysis, wherein the light intensity is measured across a wavelength spectrum, wherein the single wavelengths of the spectrum are separated off sequentially by the aid of a pivotal optical interference filter.

3. A measuring system for monitoring and measuring gases comprising a sensor head for transmitting light through the gas medium to be examined, a spectrum analyser for detecting the absorption of light having a predetermined wavelength, a source of light, and optic fibre transmission means for transmitting light from the source to sensor head and from the sensor head to the spectrum analyser, the spectrum analyser being operable to determine the absorption on the basis of the ratio between a calculated signal level based on measurements outside the predetermined wavelength and the measured signal level of the wavelength.

4. A system according to claim 3, wherein the spectrum analyser is operative to measure single wavelengths sequentially across a wavelength spectrum, a pivotal optical interference filter being provided for sequentially separating out the single wavelengths.

5. A process of gas detection substantially as herebefore described with reference to the accompanying drawings.

6. A measuring system for monitoring and measuring gases constructed and arranged to operate substantially as herebefore described with reference to and as illustrated in the accompanying drawings.

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